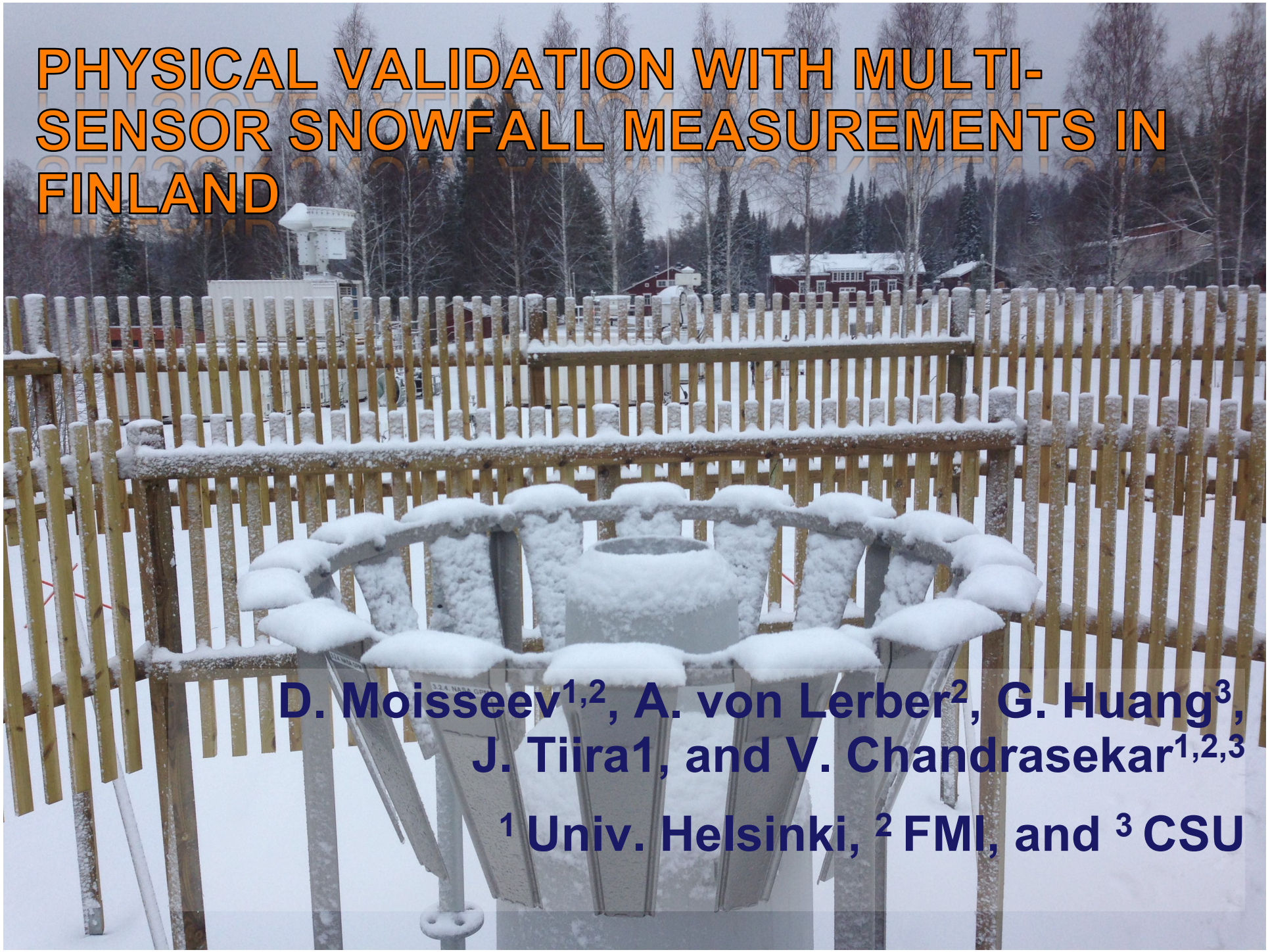


PHYSICAL VALIDATION WITH MULTI-SENSOR SNOWFALL MEASUREMENTS IN FINLAND

D. Moisseev[1,2], A. von Lerber[2], G. Huang[3], J. Tiira1, and V. Chandrasekar[1,2,3]

[1] Univ. Helsinki, [2] FMI, and [3] CSU

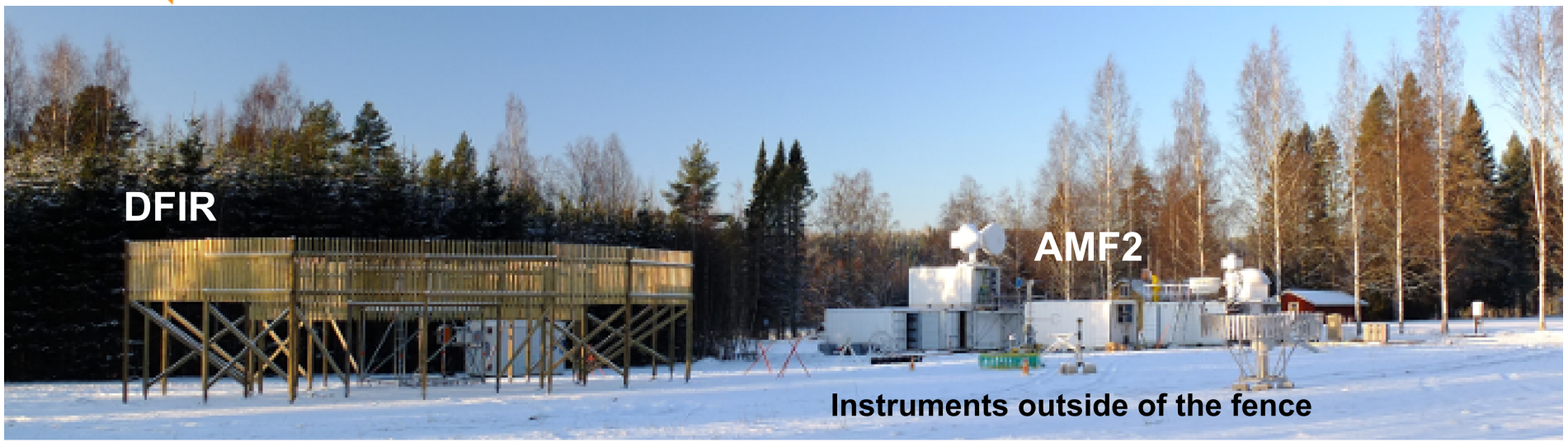
BAECC SNEX
Feb 1 – Apr 30, 2014

Quantitative estimation of snowfall microphysics to

- connect to multi-frequency and dual-pol radar observations
- give a detailed view of snow growth processes, by combining with multi-instrumental remote sensing

Quality of observations and retrievals is insured by consistency of retrieved PSD, density, v-D and m-D between instruments, methods and each other

Measurement setup



Instruments outside of the fence

Instruments inside of the fence

Micro Rain Radar

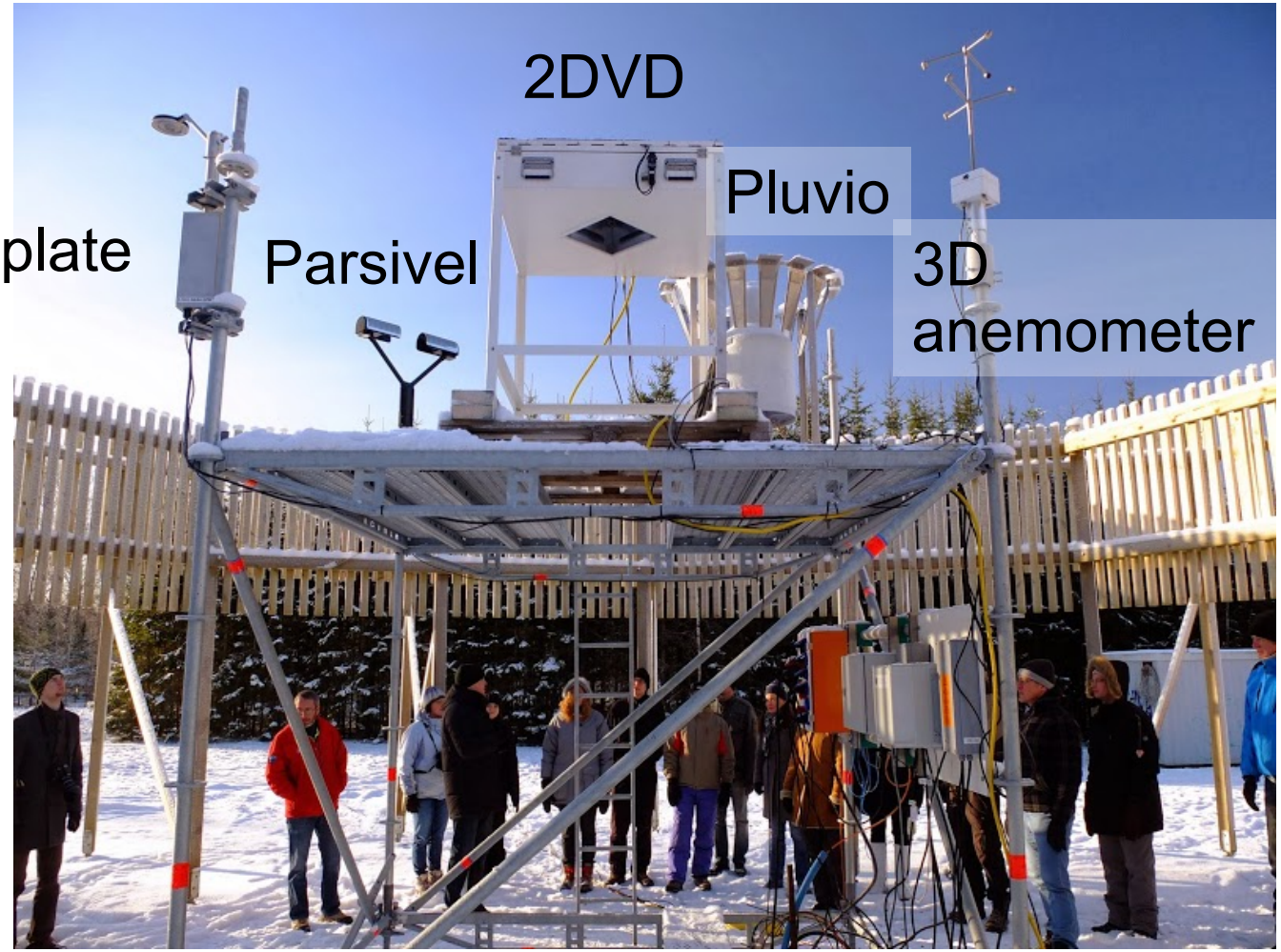
NASA Particle Image Package

Snow depth sensor and 3D anemometer

Dual fence international reference

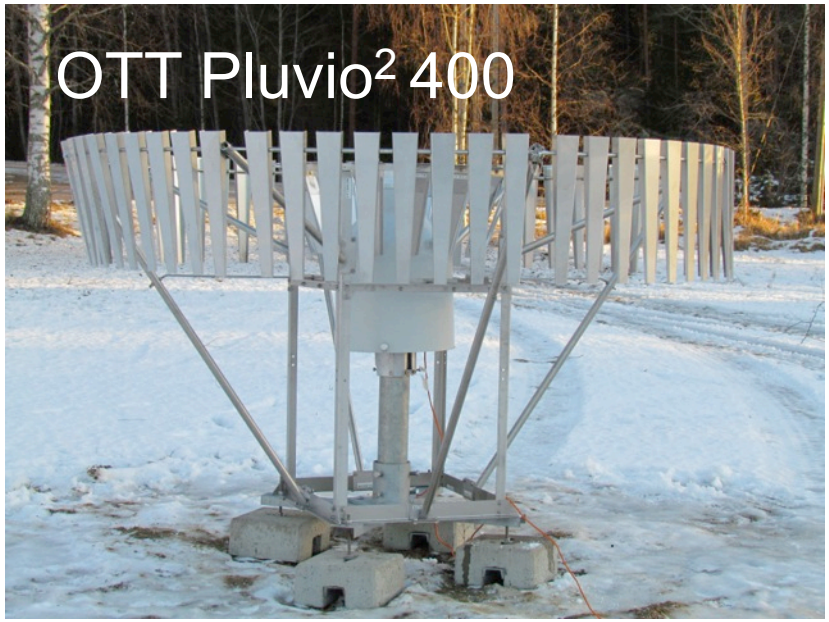
Following improved GCPEx design (according to recommendations by Peter Rodriguez, Environment Canada)

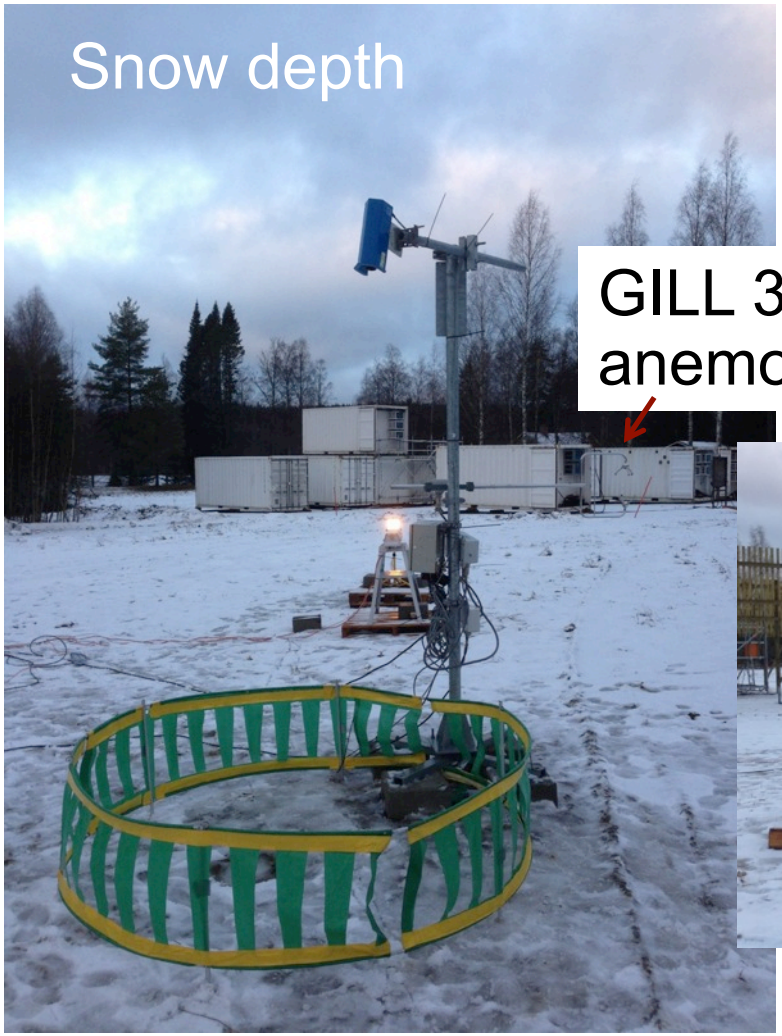
Inside of the fence

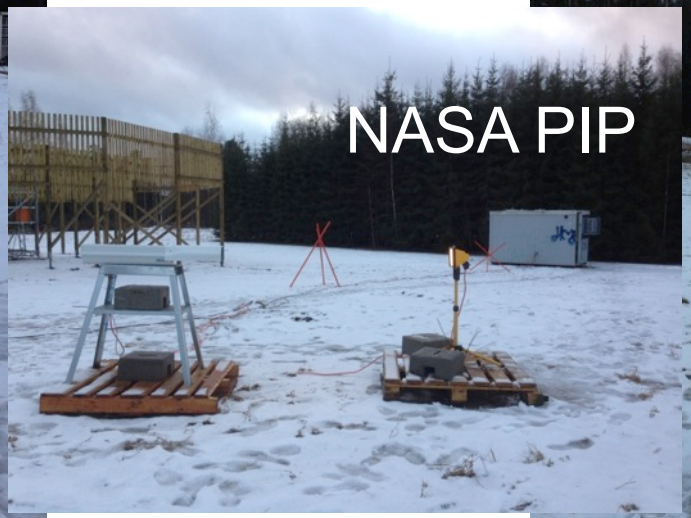


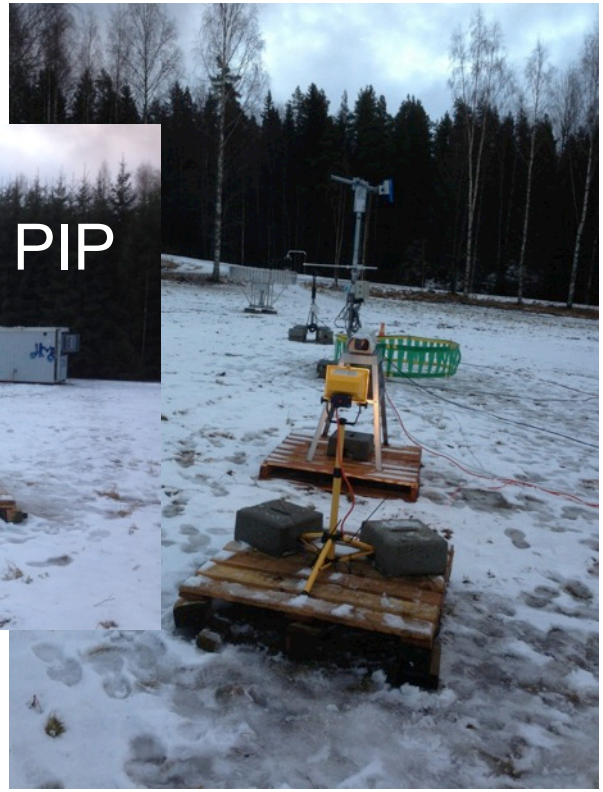
Wind measurements at instrument sampling volume heights were carried out by 3D anemometers inside and outside of the fence

Field instruments

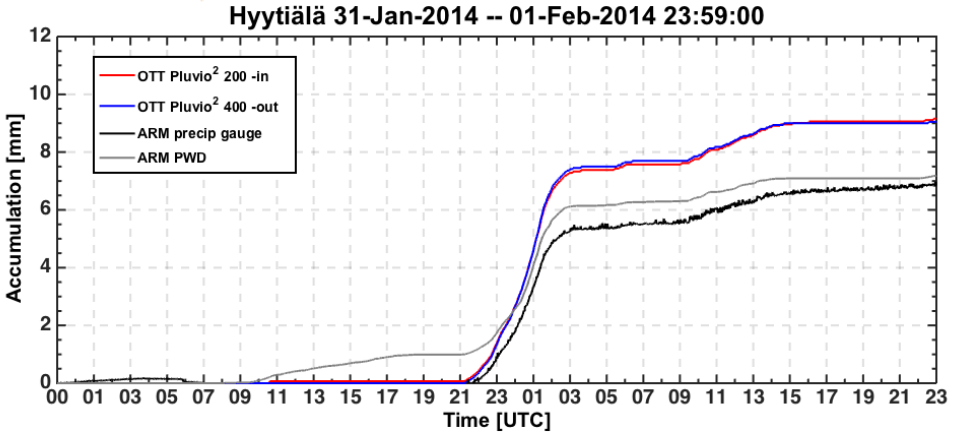


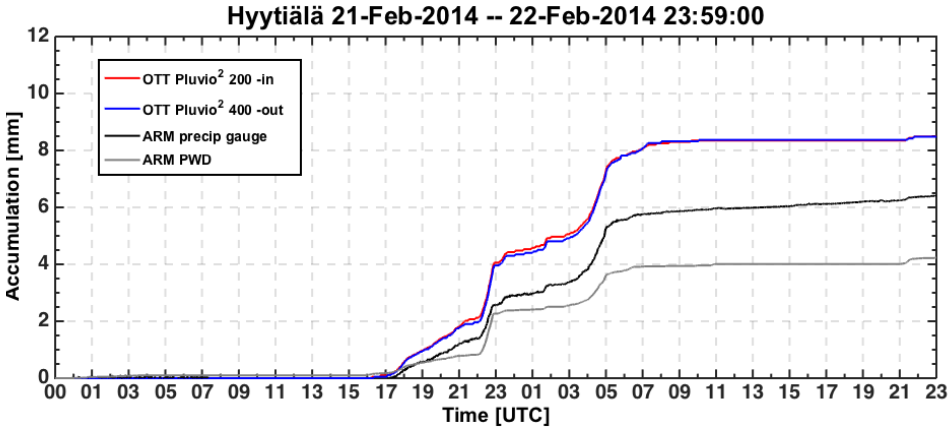


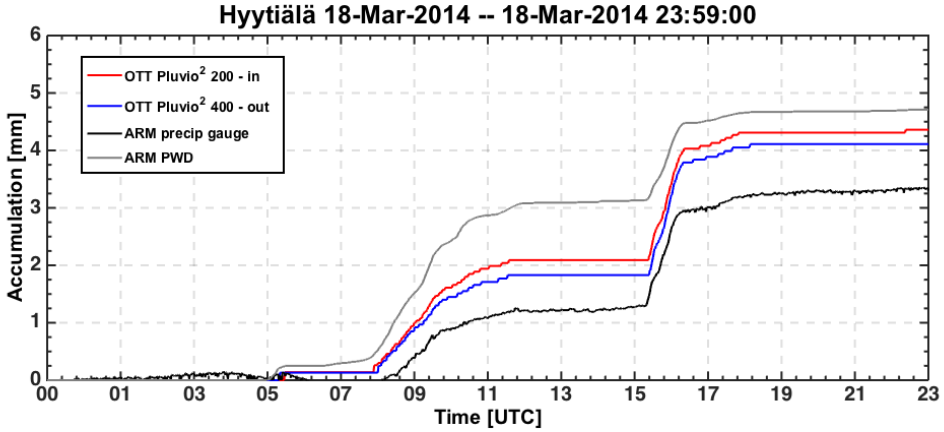


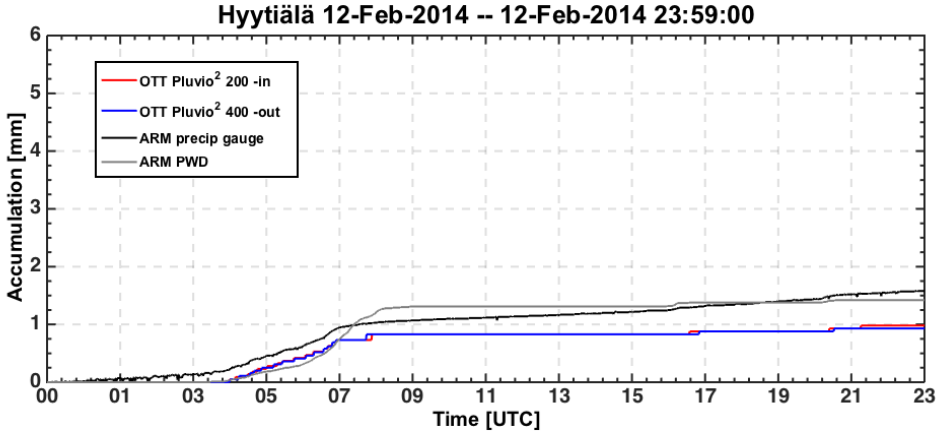


Precipitation accumulation – consistency check



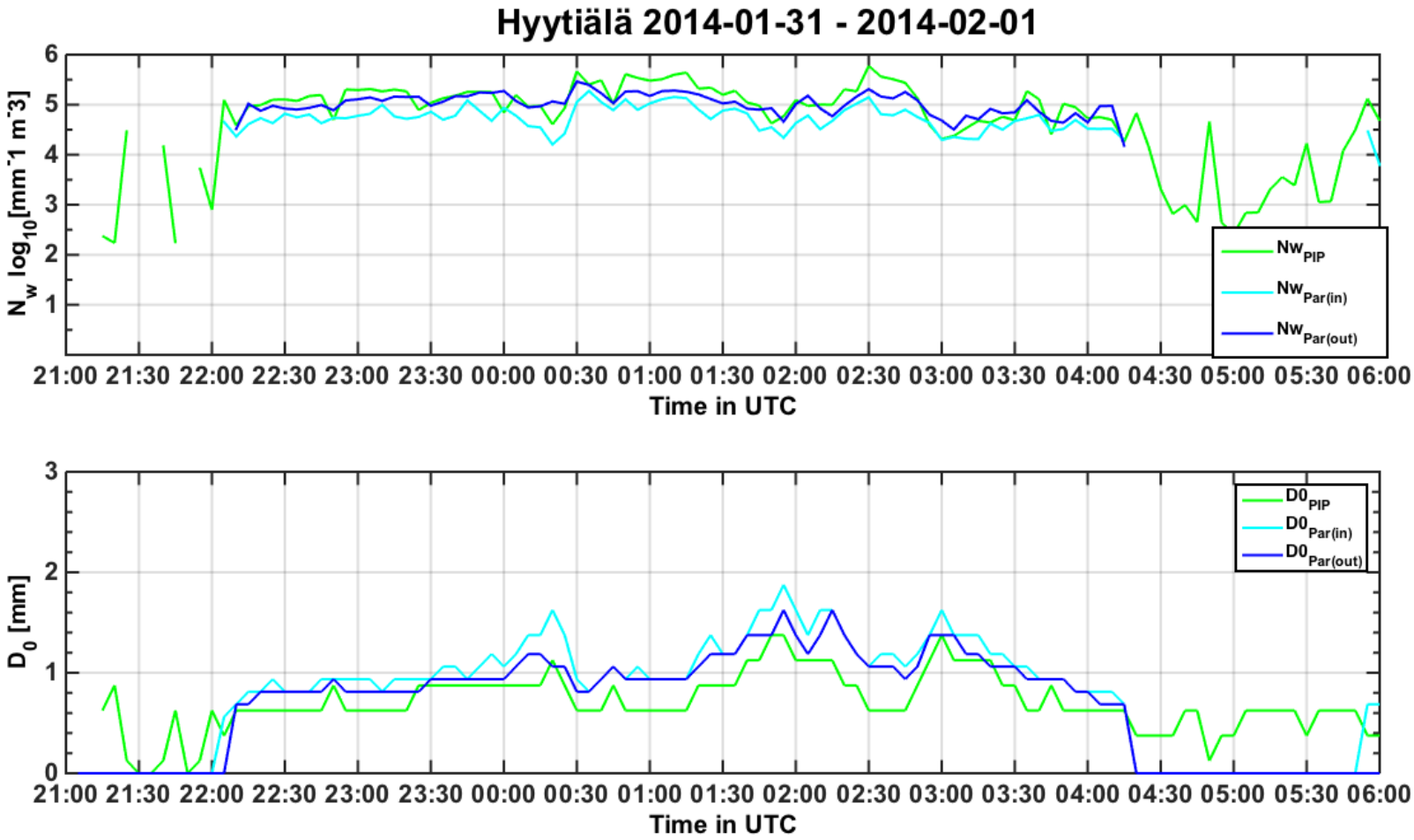




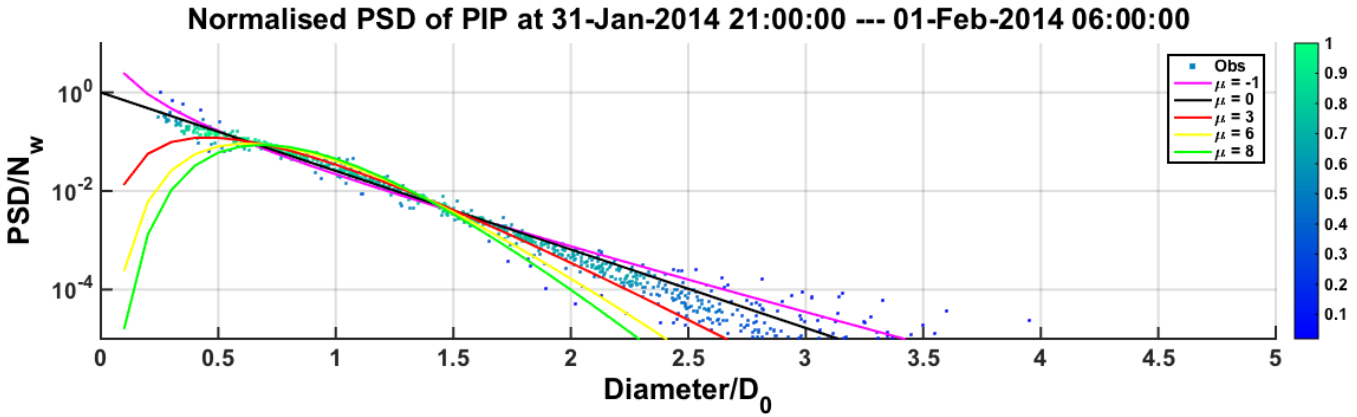


- Measurements from different instruments should agree
- Or disagree in a predictable way

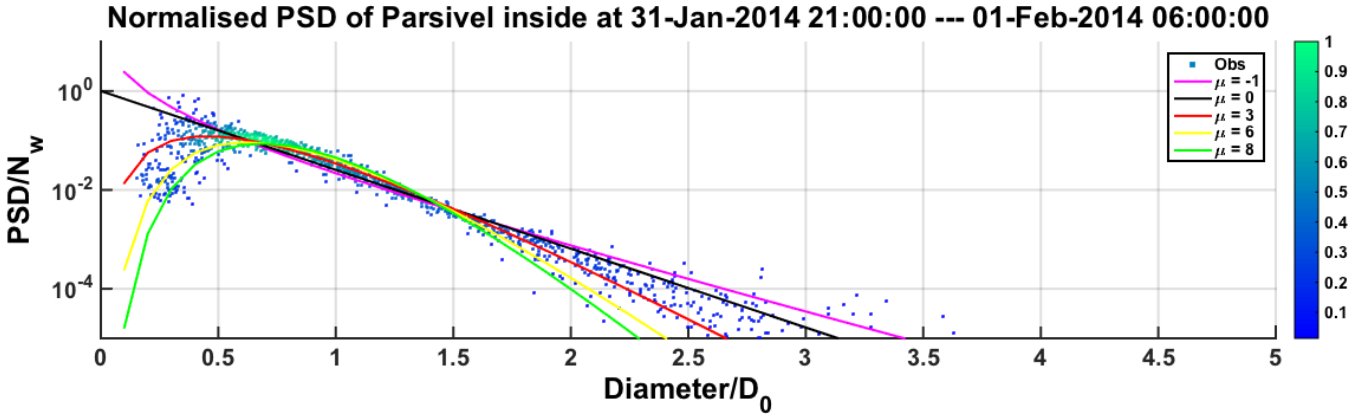
PSD observations



PSD observations



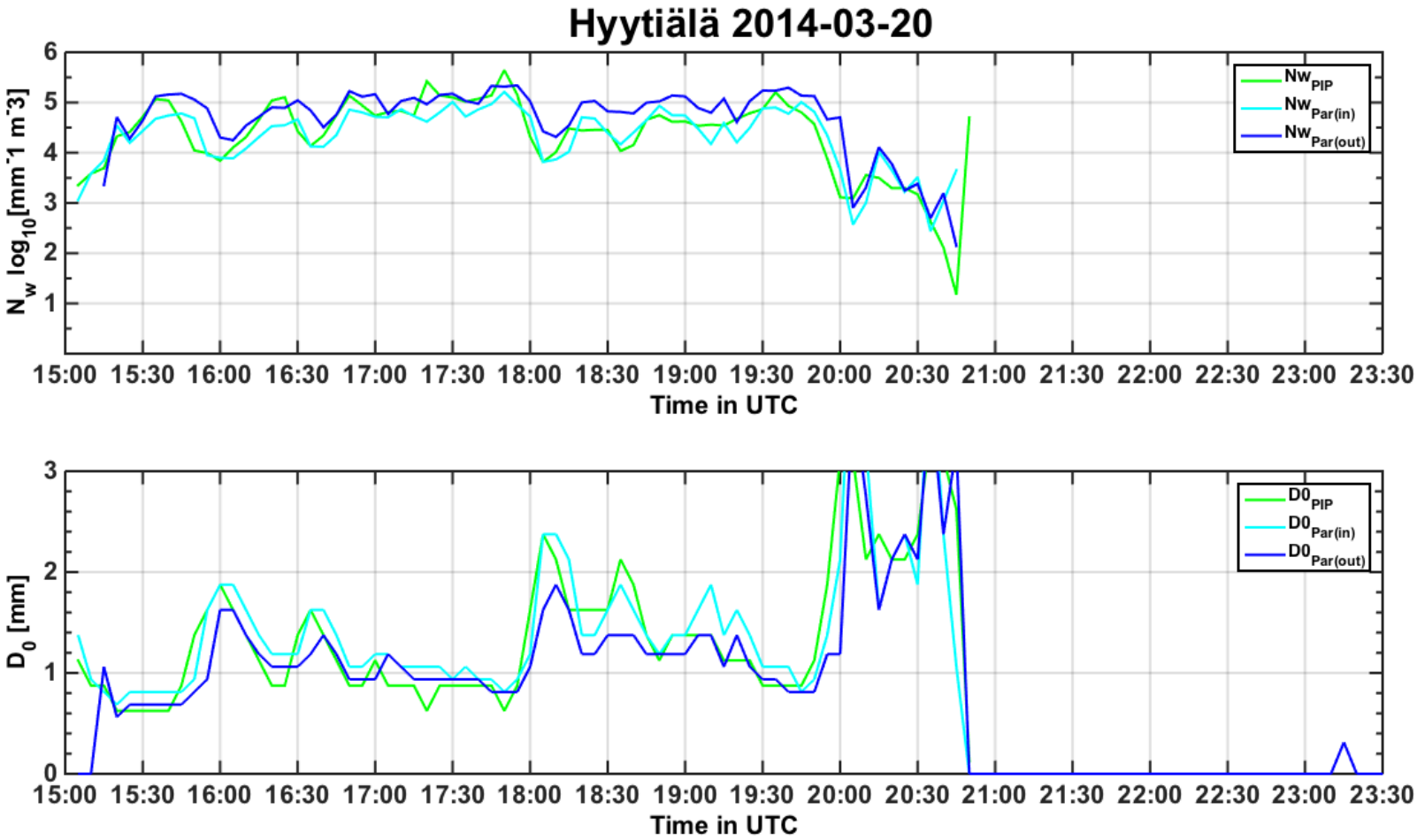
PIP



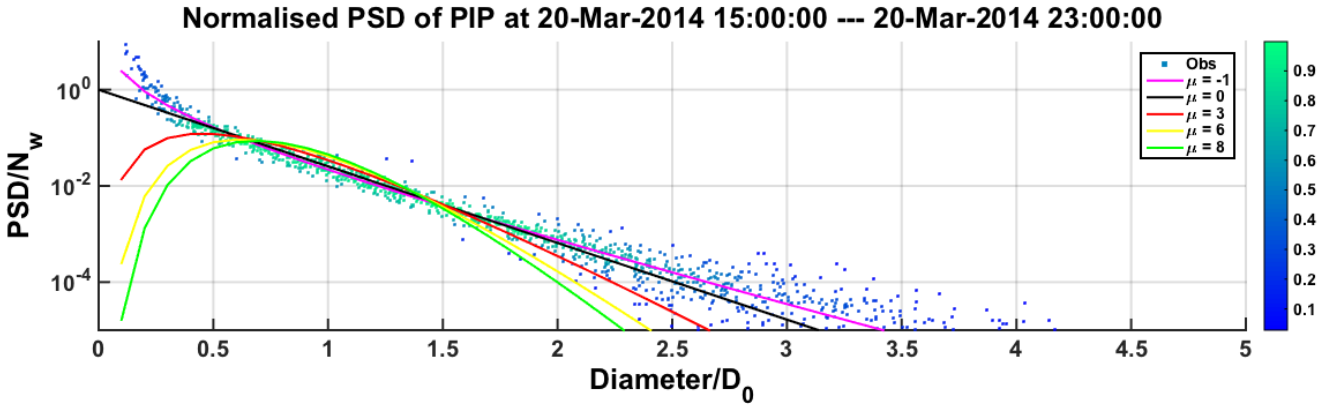
Parsivel

PIP detects (shows?) more smaller particles

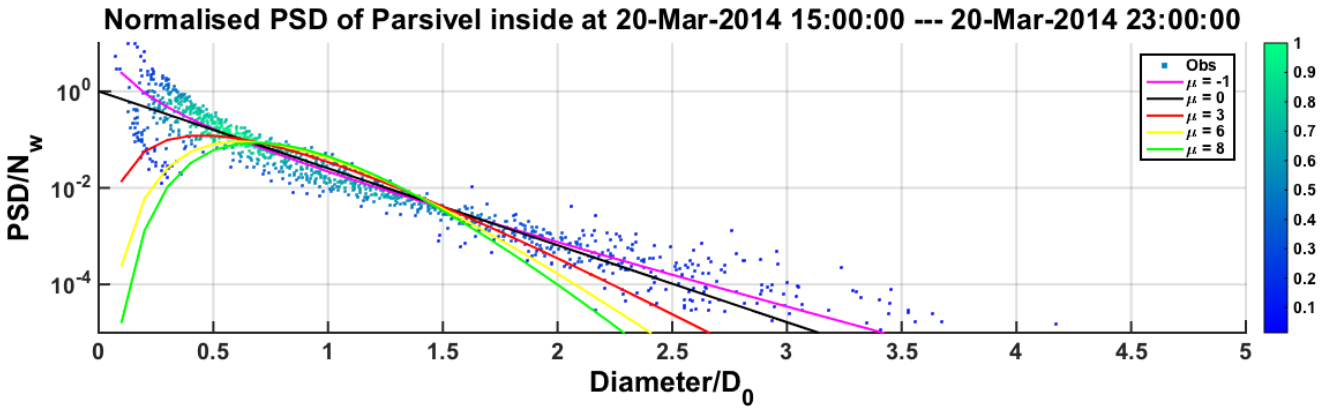
PSD observations



PSD observations – 20 March, 2014



PIP



Parsivel

PIP and Parsivel PSD shapes agree better when more smaller particles are present

Bulk density estimation
PIP and Pluvio (similar to Brandes et al. 2007)

Precip. accumulation from PIP PSD observations:

$$G_{PIP}(T) = 10^{-6} \frac{\pi}{6} \frac{\rho_b}{\rho_w} \int_{T}^{T+\Delta T} \int_{D_{\min}}^{D_{\max}} D^3 v(D,t) N(dD,t)\, dD\, dt$$

At the same time weighing gauge gives:

$$G_{WG}(T) = 10 \frac{1}{\rho_w A_G} \int_{T}^{T+\Delta T} m(t)\, dt$$

The bulk density accuracy is determined by how well N(D), v(d) and gauge accumulation can be measured.
Needs sufficient accumulation to work – No light precip. events

Bulk density – 2D-video

Following Huang et al., (2015) with basic formulation of Böhm (1989) and later modification of Heymsfield & Westbrook, (2010)

- Terminal velocity depends on Reynolds number

$$v = \frac{\eta \mathrm{Re}}{\rho_{air} D}$$

- The Reynolds number depends on Davies number

$$\mathrm{Re} = \frac{\delta_o^2}{4}\left[\left(1 + \frac{4\sqrt{X}}{\delta_0^2\sqrt{C_0}}\right)^{1/2} - 1\right]^{1/2}$$

- The Davies number

$$X = \frac{\rho_{air}}{\eta^2}\frac{8mg}{\pi}\left(\frac{A}{A_e}\right)^{1/4}$$

Bulk density – 2D-video

Depends on observations and assumptions of particle shapes !!!

Following Huang et al., (2015) with basic formulation of Böhm (1989) and later modification of Heymsfield & Westbrook, (2010)

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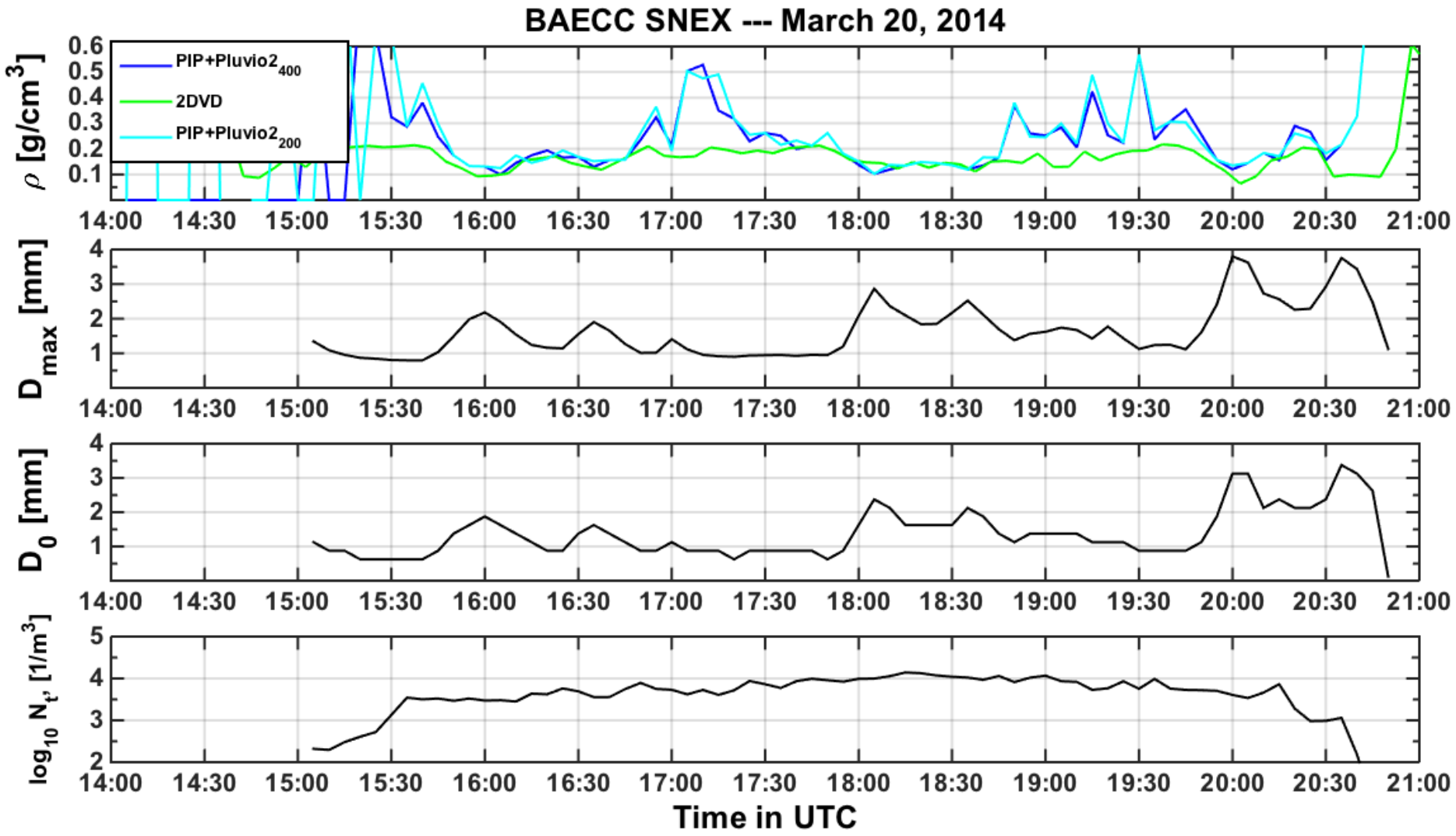
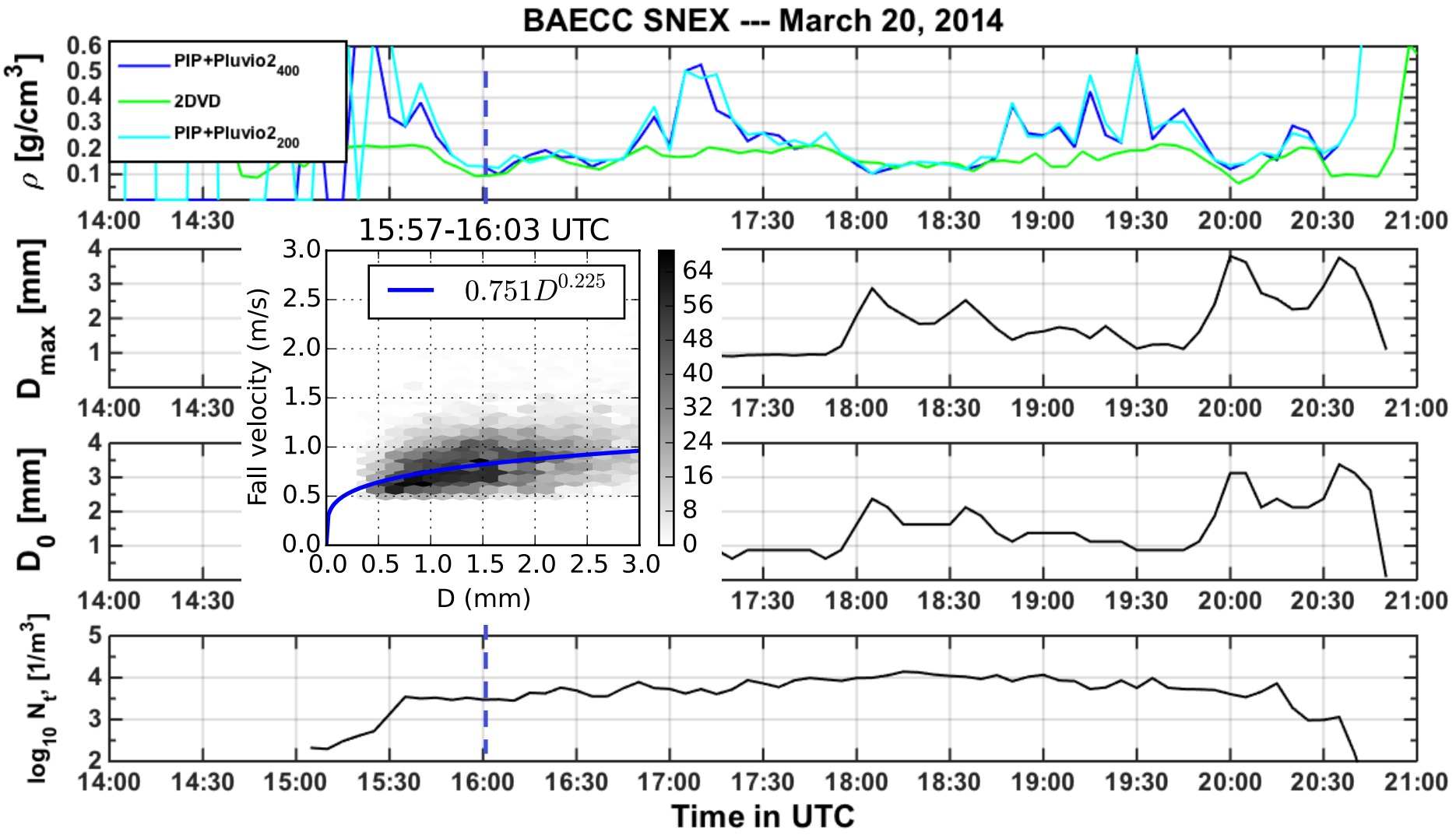
- The Davies number

$$X = \frac{\rho_{air}}{\eta^2}\frac{8mg}{\pi}\left(\frac{A}{A_e}\right)^{1/4}$$

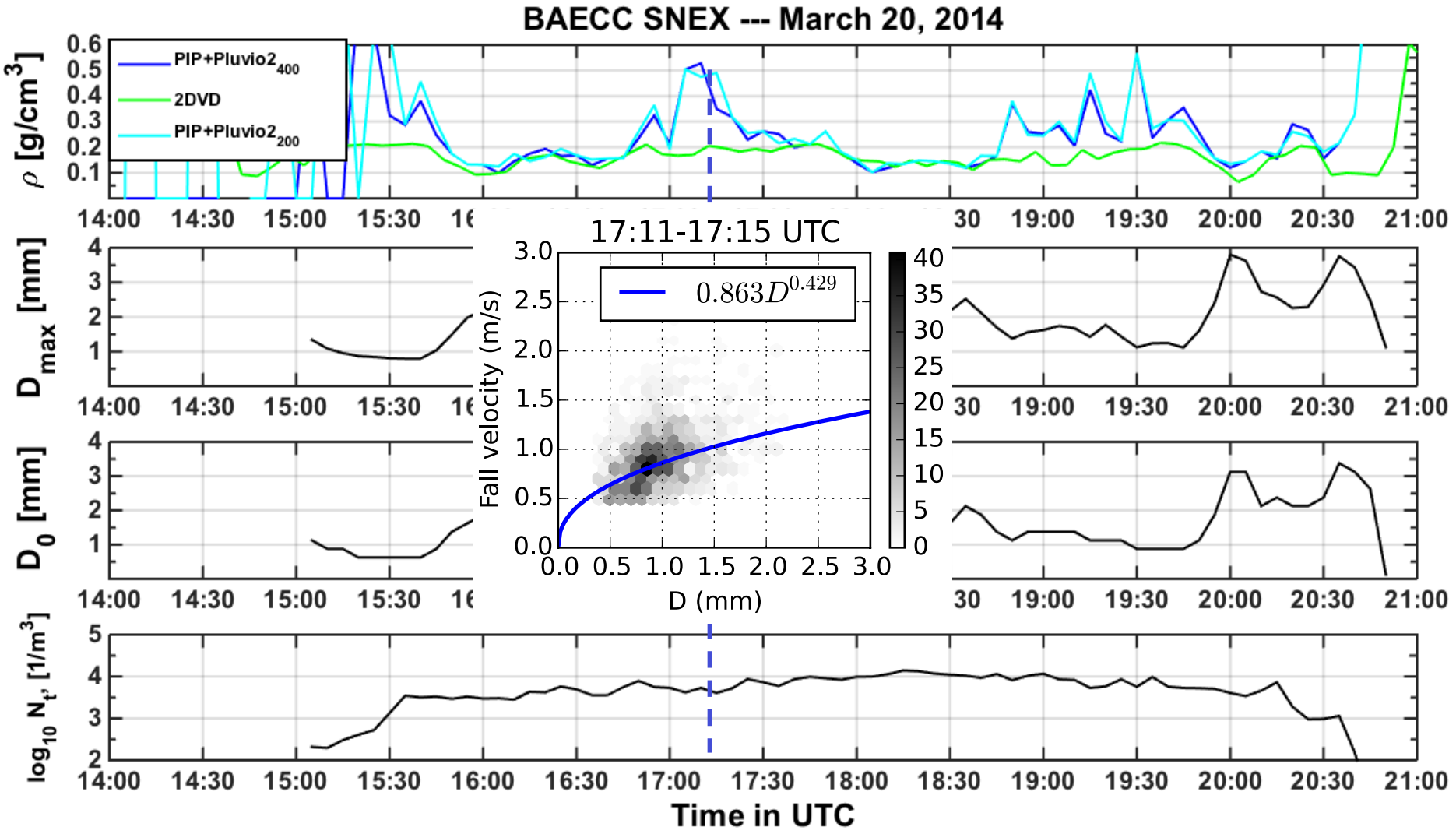
Bulk density consistency check



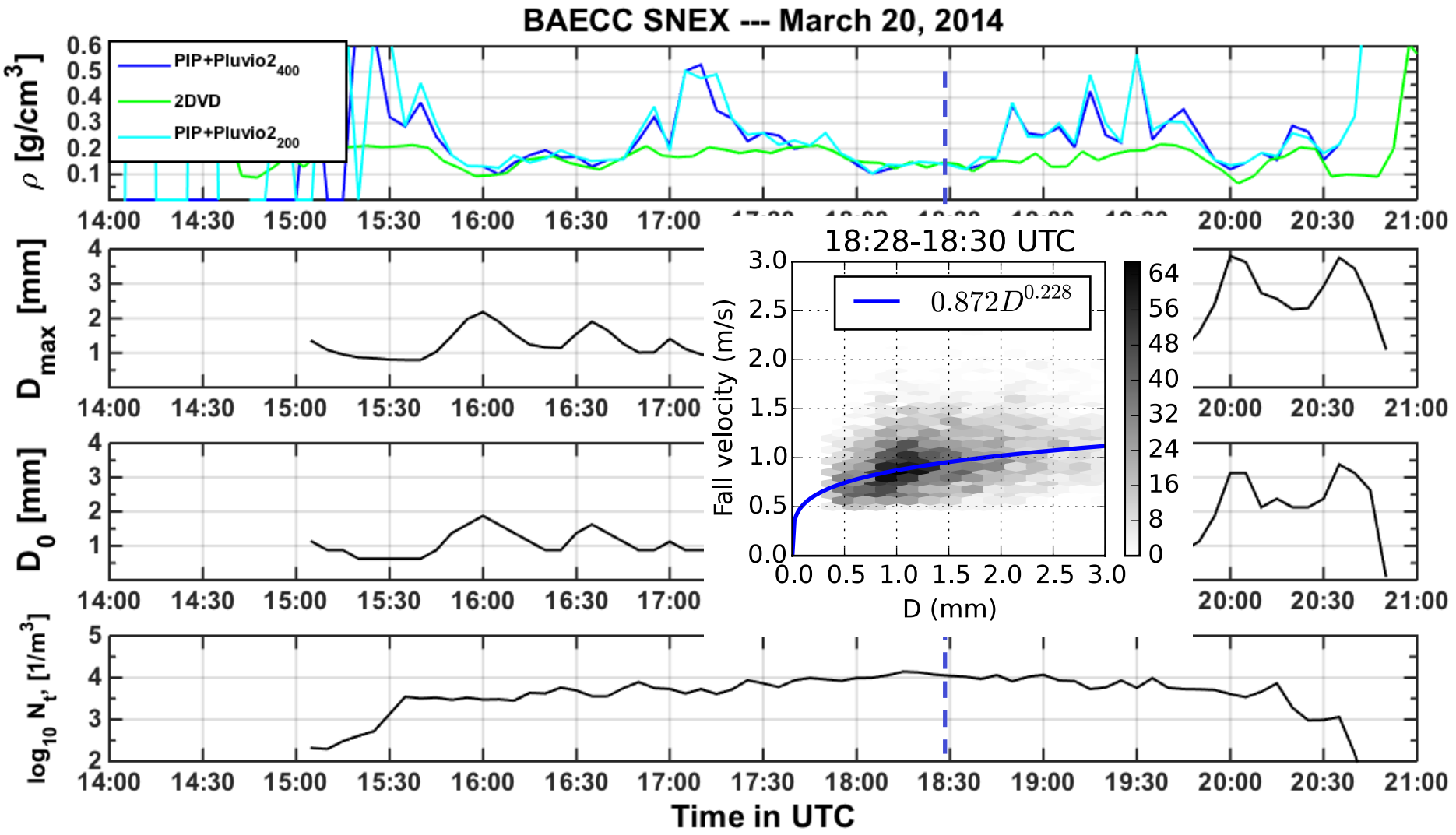
Bulk density consistency check - velocity



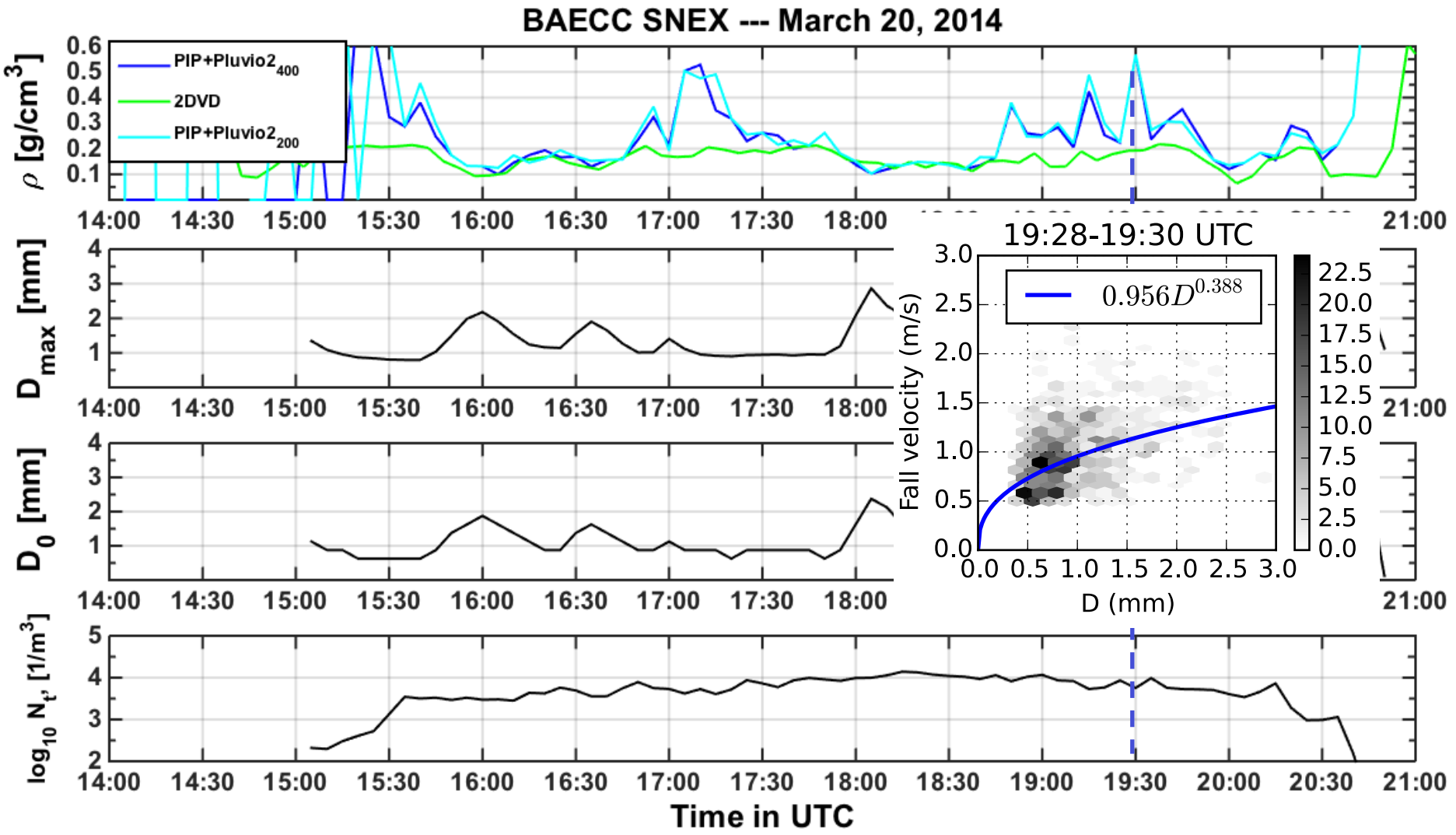
Bulk density consistency check - velocity



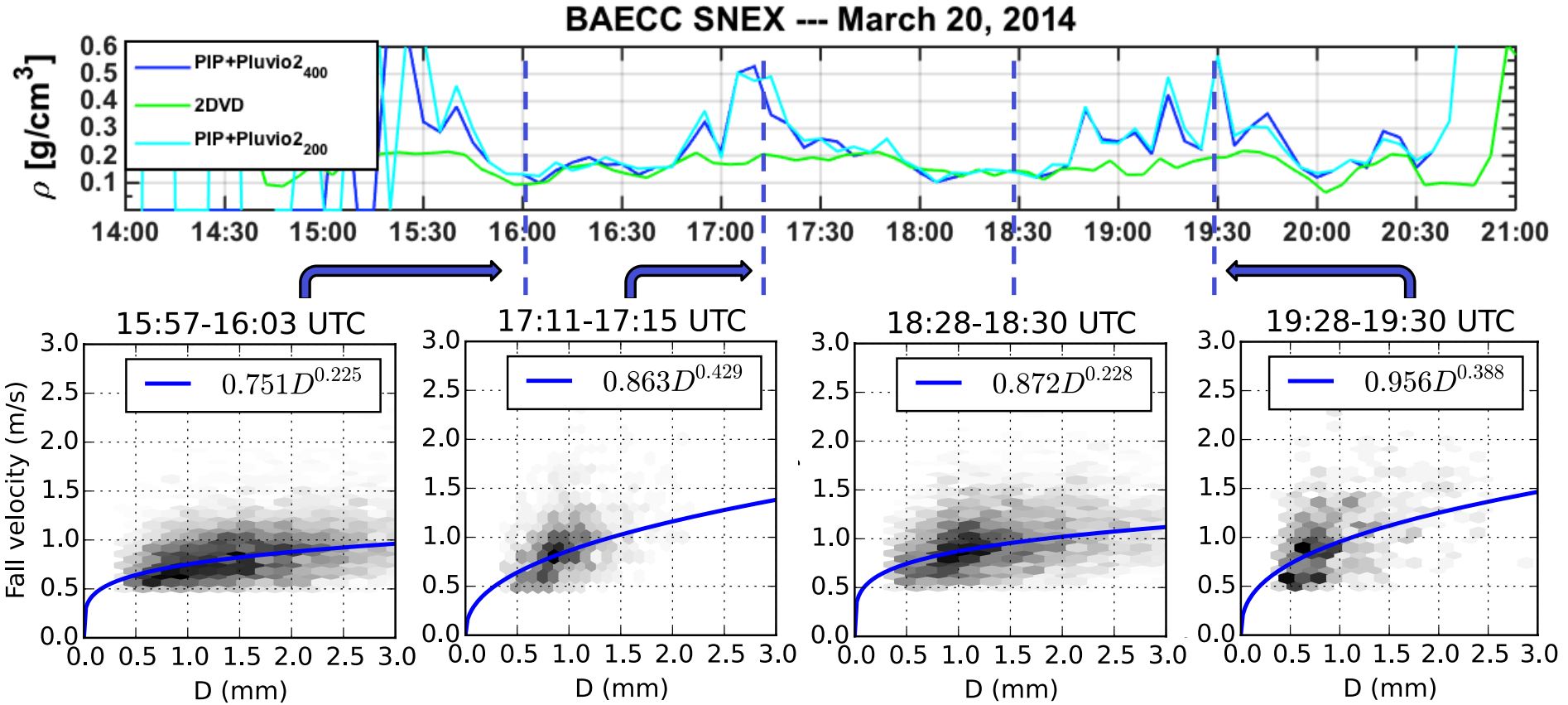
Bulk density consistency check - velocity



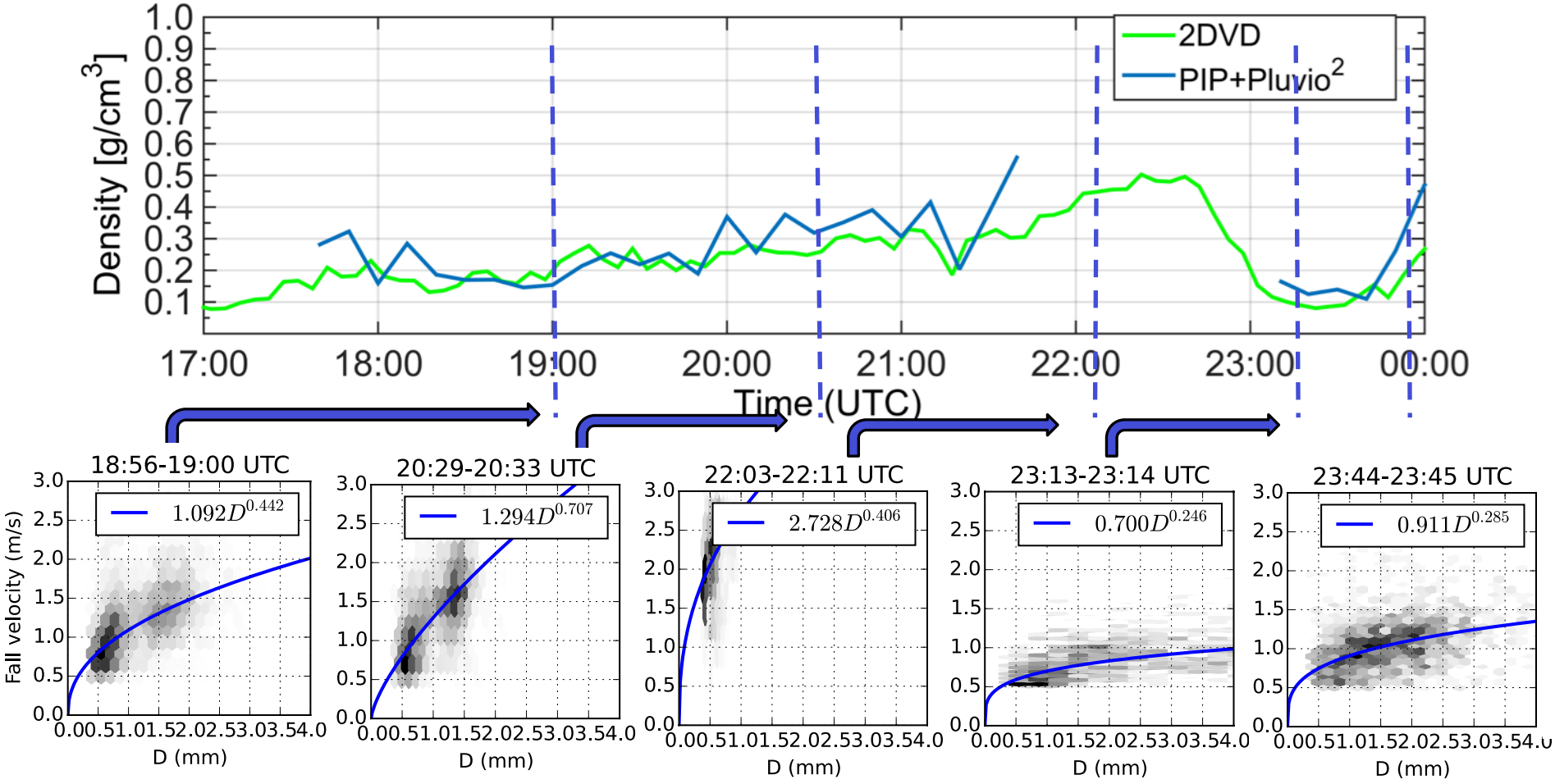
Bulk density consistency check - velocity



Bulk density consistency check - velocity

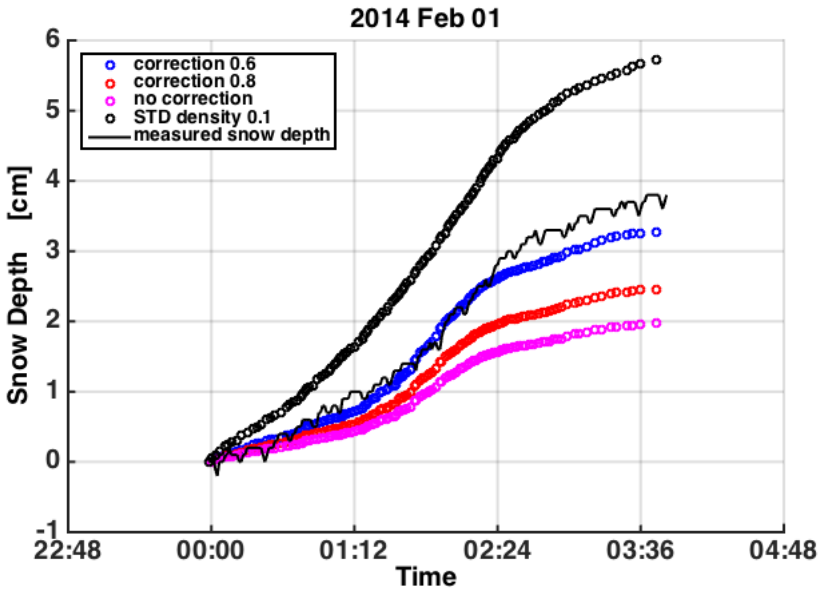


Bulk density consistency check - velocity Feb 21, 2014

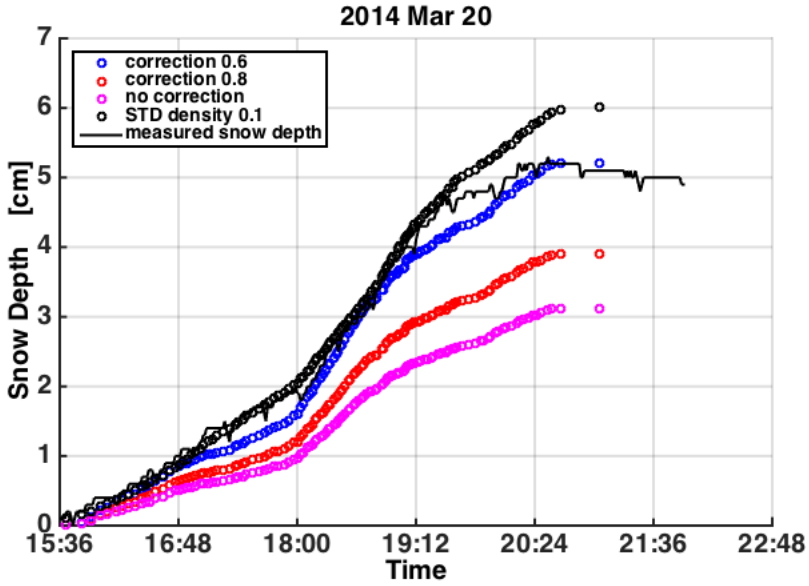


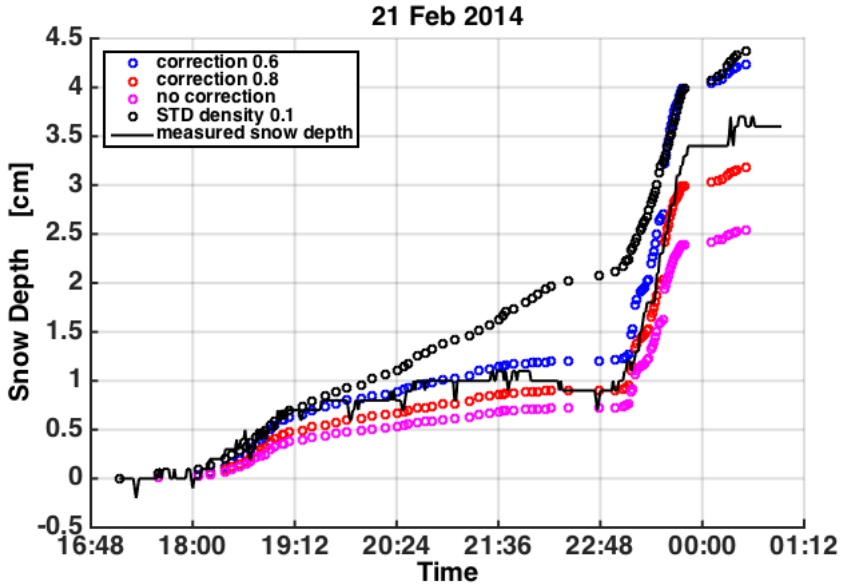
- Density retrievals are also consistent with v(D) observations

Bulk density consistency check - snow depth

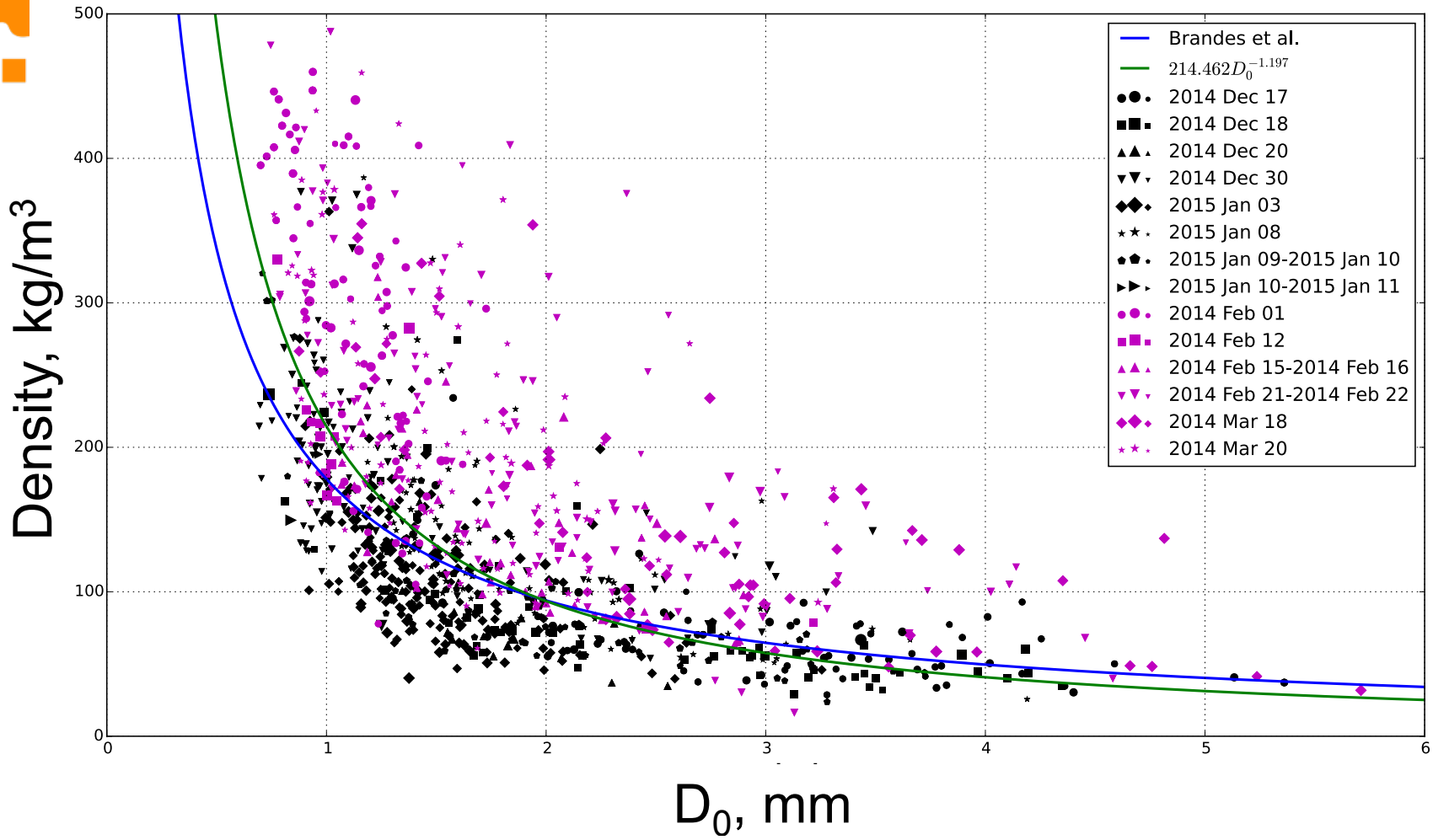


- Snow depth and LWE are often used as indicator of freshly fallen snow density
- The density estimated this way is lower than density of falling snow

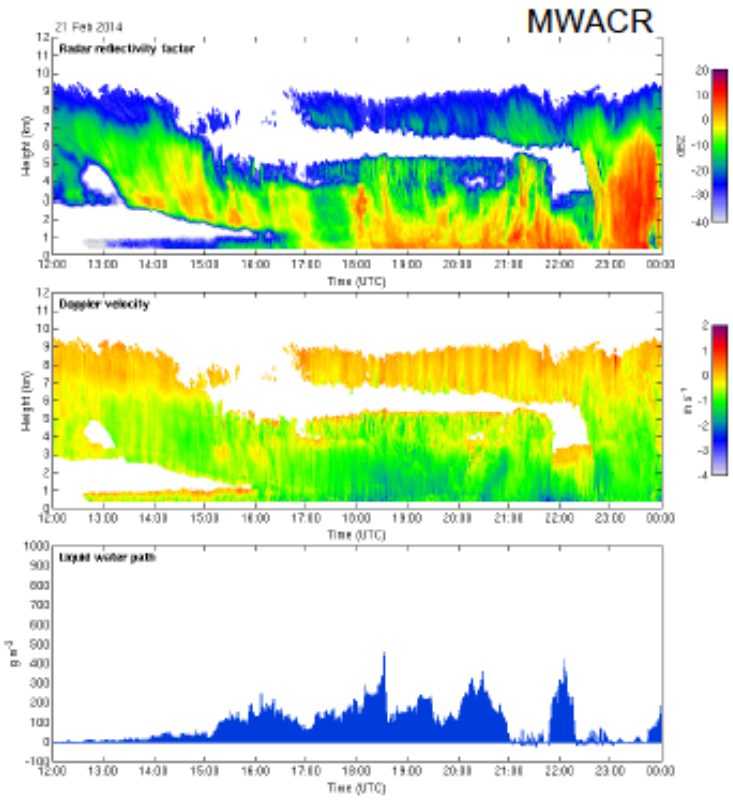


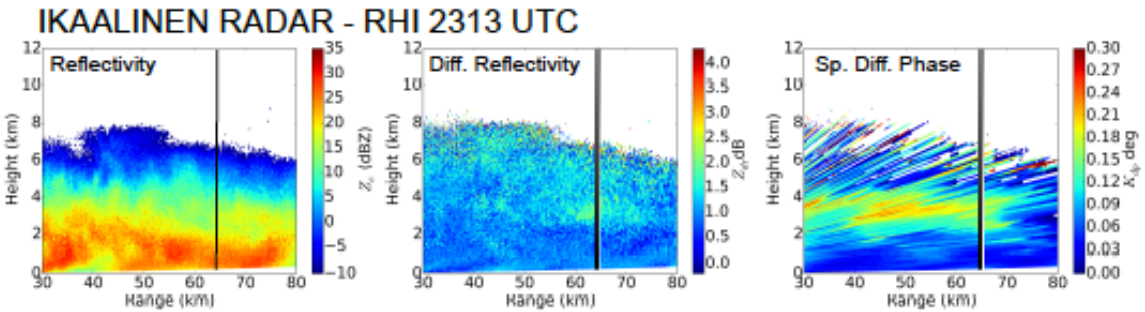


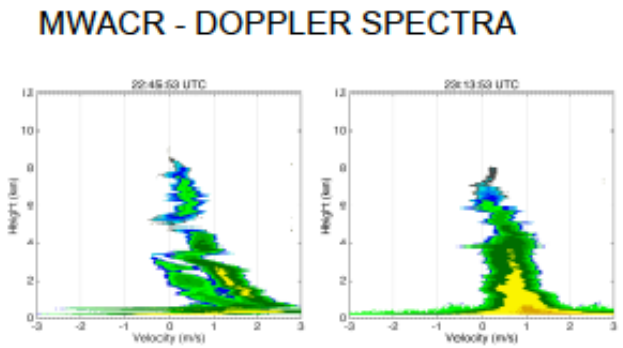
Summary of BAECC SNEX events

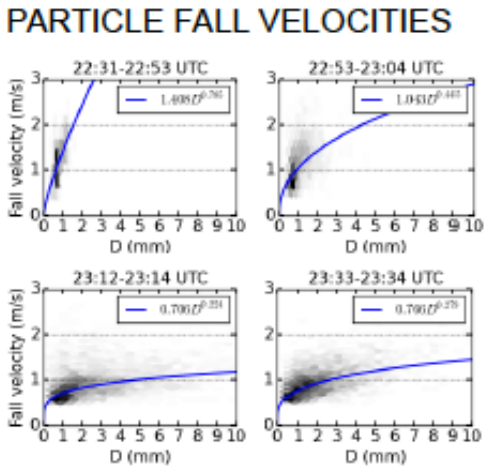


Snow during BAECC SNEX was denser than observed by Brandes et al., (2007) and denser than the one during 2014/2015

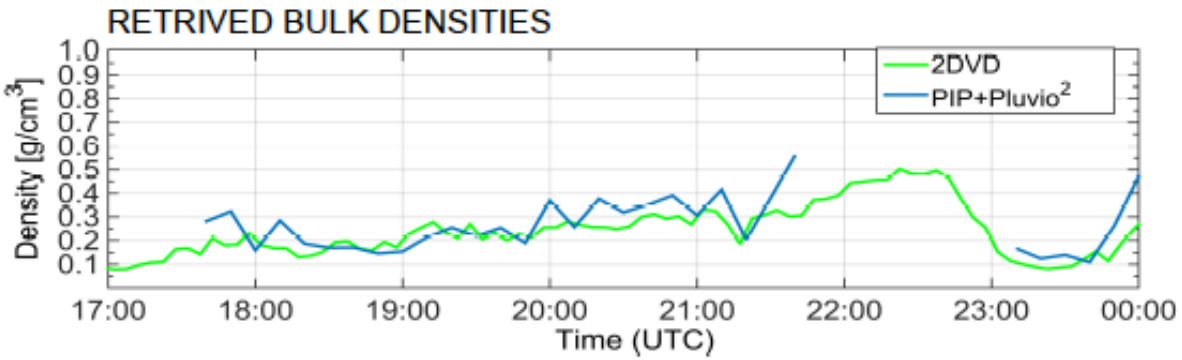








	No precip
	Crystals falling from liquid layer
	Rimed particles, 3 liquid layers
	Rimed particles, 2 liquid layers
	Aggregates, no liquid layers
	Aggregates, liquid present



Painting one picture by observations from different sources

Conclusions

- Excellent dataset of 20 snow events (combining wet and dry snow events)
- Quantitative estimation of snowfall microphysics is possible
- Quality of observations and retrievals can be verified through consistency between retrievals, different instr. Observations
- Now we need to use this data to

  - connect multi-frequency and dual-pol radar observations to snow microphysics and snow growth processes